MINERALOGY, THREE DIMENSIONAL STRUCTURE, AND OXYGEN ISOTOPE RATIOS OF FOUR CRYSTALLINE PARTICLES FROM COMET 81P/WILD 2. T. Nakamura[1], T. Noguchi[2], A. Tsuchiyama[3], T. Ushikubo[4], N. T. Kita[4], J. W. Valley[4], M. E. Zolensky[5], Y. Kakazu[1], K. Sakamoto[1], E. Mashio[3], K. Uesugi[6], and T. Nakano[7] [1] Department of Earth and Planetary Science, Faculty of Science, Kyushu University, Hakozaki, Fukuoka 812-8581, Japan (tomoki@geo.kyushu-u.ac.jp), [2]Department of Materials and Biological Sciences, Ibaraki University, 2-1-1 Bunkyo, Mito 310-8512, Japan, [3]Department of Earth and Space Science, Graduate School of Science, Osaka University, Toyonaka 560-0043, Japan, [4]Department of Geology and Geophysics, University of Wisconsin-Madison, Madison, WI 53706-1692, USA, [5]KT NASA Johnson Space Center Houston, TX 77058, USA, [6]Japan Synchrotron Radiation Research Institute, SPring-8, Sayo, Hyogo 679-5198, Japan, [7]Geological Survey of Japan, Advanced Industrial Science and Technology, Tsukuba 305-8567, Japan.

Introduction: Preliminary examinations of small dust particles from comet 82P/Wild 2 revealed many expected and unexpected features [e. g., 1. 2]. Among them the most striking feature is the presence of abundant crystalline material in the comet. Synchrotron radiation X-ray diffraction and micro-tomography are the most efficient methods to detect and describe bulk mineralogical features of crystalline cometary particles [3, 4]. In the present study, in addition to these two non-destructive techniques, electron microscopy and ion-probe mass spectrometry were carried out on the four crystalline particles.

Experimental procedures: Systematic screening was performed in order to detect crystalline particles. All allocated particles were first exposed to synchrotron X-rays at KEK to obtain diffraction patterns [3]. Crystalline particles were next exposed to synchrotron X-rays at SPring-8 to image three dimensional structures [3, 4]. Based on the results of tomography with sub-micron resolution, the four crystalline particles showing igneous structure were chosen for further analysis. Individual particles were embedded in epoxy resin and microtomed to make thin foils for TEM investigation [5]. Approximately half of each particle was left in potted butts, which are used for further electron- and ion-microprobe analyses. The potted butts were embedded again in epoxy resin with one San Carlos olivine standard grain and polished to have flat surfaces. The sample mounts were finished as polished disks (one sample and one olivine particle/each exposed on the surfaces).

Each particle was observed by FE-SEM at University of Tokyo through the courtesy of Dr. Nagahara for micro-texture and analyzed by electron probe at Kyushu University for mineral chemistry. Then oxygen isotope analysis was performed at University of Wisconsin-Madison using CAMECA IMS 1280 [6]. By using focused Cs^+ beam with 1 μm diameter and multicollection system with both Faraday Cup (^{16}O ~3M cps) and electron multipliers (^{17}O and ^{18}O), we obtained several to ten high precision (1-2‰) oxygen isotope ratios from each stardust particle.

Results and discussion:

Gozen-sama (C2081,1,108,1) This is the largest terminal particle (40μm diameter) taken from track 108 with 13mm in length. Synchrotron X-ray diffraction (S-XRD) analysis showed that well-crystalline olivine and low-Ca pyroxene are major phases and kamacite is a minor phase. Tomography analysis showed that the particle contains many small round FeNi metal inclusions. Small amounts of melted aerogel + Fe-rich cometary material is present with a discrete sharp boundary to the surface of the particle.

Electron microscopy of polished surface indicated that it has poikilitic texture in an entire region: two sub-round olivine (7 and 15μm in diameter for Ol-1 and Ol-2, respectively) set in low-Ca pyroxene. Ol-1 is Fo_{95} with trace concentrations of MnO 0.5wt%, Cr_2O_3 0.5wt%, CaO 0.1wt%. Core-rim Fe-Mg zoning is not observed. Ol-2 is Fo94 with MnO 0.2-0.4wt%, Cr_2O_3 0.5wt%, CaO 0.1wt%: Ol-2 is slightly richer in FeO and poorer in MnO. Low-Ca pyroxene is homogeneous at $En_{95}Wo_1$ with Al_2O_3 0.8wt%, TiO_2 0.2wt%, MnO 0.1-0.3wt%, Cr_2O_3 0.5wt%.

Ion-microprobe analysis (10 points) showed that the particle is very heterogeneous in oxygen isotope ratios (-45 to +5 ‰: Fig.1). Ol-1 is most enriched in ^{16}O ($\delta^{18}O$ from -45 to +2 ‰), while Ol-2 is depleted in ^{16}O ($\delta^{18}O$ from +2 to +5 ‰). Low-Ca pyroxene showed intermediate composition between the two olivine grains. Grid analyses with 2μm interval over 10μm square (36 points) were performed on the portion containing ^{16}O-rich hot spot in Ol-1. The results revealed that it contains 3 x 5μm core area that is highly enriched in ^{16}O ($\delta^{18}O$ < -10 ‰) and $\delta^{18}O$ of its rim is close to that of low-Ca pyroxene enclosing

the Ol-1. Similarly, 4-point line analyses in Ol-2 indicate core-rim zoning of oxygen isotope ratios and the rim has composition close to surrounding low-Ca pyroxene.

The above results suggest that Gozen-sama is a product of partial melting at peritectic temperature of ~ 1550 °C. During heating, rims of Ol-1 and -2 were melted and recrystallized, resulting in oxygen isotope equilibrium with surrounding low-Ca pyroxene, whereas cores of Ol-1 and -2 were not melted and retained their initial oxygen isotopic ratios. Low-Ca pyroxene was crystallized from melt, which is supported by uniform oxygen isotope ratios.

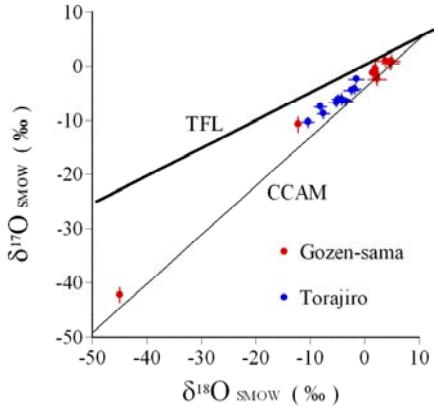

Fig. 1. Oxygen isotope ratios of Gozen-sama and Torajiro.

Torajiro (C2054,0,35,6, 0). This is a terminal particle of a sub-track branched from main-track #35 with 11mm in length. It is a non-porous aggregate consisting of highly crystalline olivine, low-Ca pyroxene, and kamacite. Melted aerogel is present on the surface of the particle. Electron microscopy of the polished surface shows both poikilitic and porphyritic textures. The poikilitic region consists olivine phenocrysts (Fo_{80} and MnO 0.8wt%, Cr_2O_3 0.2wt%, CaO 0.4wt%) and low-Ca pyroxene oikocryst ($En_{88}Wo_3$ and Al_2O_3 1-2wt%, TiO_2 0.2wt%, MnO 0.4wt%, Cr_2O_3 0.8wt%). In the porphyritic region, olivine is similar in composition but pyroxene is slightly depleted in MgO compared to those in the poikilitic region. In the poikilitic region Cr-rich spinel occurs, while in the porphyritic region kamacite and SiO_2- and Al_2O_3-rich mesostasis glass occur.

In-situ isotope measurement (11 points) indicated that Torajiro is heterogeneous in oxygen isotopic ratios (Fig. 1), but total range of distribution is narrower than Gozen-sama. $\delta^{18}O$ of olivine in both poikilitic and porphyritic regions is from -8 to -4‰. On the other hand, $\delta^{18}O$ of low-Ca pyroxene in the porphyritic region is richer in ^{16}O ($\delta^{18}O$ = -10 to -5‰) than that in the poikilitic region (-2 to -1‰). The heterogeneous oxygen isotopic ratios along the slope 1 line suggest that Torajiro was also formed through partial melting of precursor material with various oxygen compositions.

Gen-chan (C2081,1,108,7) This is a terminal particle 20 x 10 μm in size of a subtrack of the track 108. The dominant crystalline phase is clinopyroxene. Observation of the polished surface shows a single crystal of Mn-rich pyroxene ($En_{84}Wo_{11}$ and Al_2O_3 3wt%, TiO_2 0.3wt%, MnO 5wt%, Cr_2O_3 1.5wt%) and SiO_2- and Al_2O_3-rich glass. The glass (2 x 3μm) is enclosed by the pyroxene, suggesting that both formed by melting. Oxygen composition of the pyroxene is constant at $\delta^{18}O$ = +2 ‰ close to CCAM line.

Lilly (C2054,0,35,4,0) This is not a terminal 10 x 15μm particle extracted from a portion close to Torajiro. The particle consists of olivine, low-Ca pyroxene, and plagioclase. Observation of the polished surface shows that a pyroxene (7 x 10 μm in size, $En_{91}Wo_4$ and Al_2O_3 2wt%, TiO_2 0.3wt%, MnO 2wt%, Cr_2O_3 2wt%) in contact with Mn-rich olivine (Fo_{90} and MnO 2wt%, Cr_2O_3 0.3wt%, CaO 0.2wt%) and SiO_2- and Al_2O_3-rich glass or plagioclase. Small chromite grains less than 100nm in size are entrained at the boundary between pyroxene and olivine. Ion-microprobe analysis was not performed on this particle due to heavy cracking during polishing.

All four analyzed particles have experienced igneous processes during formation, which is supported by the presence of poikilitic or porphyritic textures and the glass phases that are enclosed in, or directly in contact to, silicates. This suggests that the particles are pieces of chondrules. The range of oxygen isotope ratios, and major and minor element concentrations of silicates in the four particles are very similar to those of silicates in chondrules in carbonaceous chondrites. Thus, we suggest that Wild 2 contains chondrules that are similar to type I and type II chondrules in carbonaceous chondrites.

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